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ABSTRACT

A study tested the possibility that children 16-24 months old and 6-7 years old can code distance without the use of landmarks. Younger children sat with their mothers at the side of a sandbox and watched the experimenter hide a toy in the sand. After being distracted, the children looked for the toy in the box. Nine trials were used, with toys hidden at locations six inches apart. For the older children, 19 trials were used, with toys hidden three inches apart. Both groups of children correctly coded the locations of the hidden objects. A second study tested the possibility that children divide space in a hierarchical organization. Children of 4, 6, 8, and 10 years were shown a page which contained a rectangle with a dot and a page with a blank rectangle. Subjects were to draw a dot in the blank rectangle in the same position in which they had seen it in the first rectangle. For subjects of all ages, the pattern of response showed bias outward from the center, and inward from the edges, of the rectangle, indicating that subjects were dividing the space in half in making their location judgments. This pattern is identical to adult patterns of spatial coding. Fourteen figures are attached. (BC)

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The Coding of Spatial Location by Young Children

Janellen Huttenlocher, Nora Newcombe, and Elizabeth Hollister

SRCD Meeting, April 1991

ED339456

In this talk I will discuss two studies I have done in collaboration with Nora Newcombe and Elizabeth Hollister. These studies are concerned with the representation of spatial location in young children. The first study shows that, even in the second year of life, children, like adults, can locate objects in space, measuring "by eye" their distance from landmarks. The second study shows that, at least by 4 years, children not only use distance from landmarks in coding location, but also, like adults, can code location within larger sections of a space. That is, 4 year olds can code location hierarchically.

Let me start with the coding of distance. Existing studies show that even in the first year of life children can code the location of an object which is adjacent to a landmark such as a cover. By a year, they can differentiate which of a pair of identical adjacent landmarks covers a hidden object. It is commonly believed that these children code locations of objects in relation to their own bodies. Indeed the one-year-old child must remain in a fixed position to do the task unless the two covers are saliently different from each other. By 18 months, children can find a hidden object even if their own position relative to the covers changes (Reiser and Hyman, 1982; Acredelo, et al, 1984). However, the question of whether these children code the location of objects in space as adults do has not been addressed. In one view, they keep track of location after movement by coding the extent of that movement in relation to the hidden object. With respect to coding the location of an object independently of the self, it is widely believed that only juxtaposition of an object and a landmark can be coded.

Yet the ability to measure distance from landmarks is essential in coding the locations of objects unless those objects happen to be adjacent to distinctive landmarks. That is, with distal landmarks, distance must be used to locate an object in a plane--either two distances using xy coordinates, or distance and angle using polar coordinates. What we mean by measurement of

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distance here is not the use of measuring instruments, but rather the estimation of distance by eye. We will examine whether distance coding in this sense emerges earlier than some would expect.

Consider two studies which have been taken as evidence that young children cannot use distance in coding object location. Piaget presented 4 and 5 year old children with arrays of objects in a display village. The children then were shown a model of a display village presented in a different orientation. They demonstrated their ability to code location by reconstructing the array on the model. Only targets which were contiguous with or surrounded by distinctive landmarks in the display village were placed correctly. There are reasons why children might fail at this task even if they can use distance in coding location. First, the model was rotated with respect to the original array. Even adults may have difficulty in establishing location when maps or models are oriented differently than the space they represent. Second, even if the model and the display villages were oriented in the same way, having to use a model at all could be problematic. The ability to understand the mapping between the two displays could, potentially, emerge later than the ability to use distance in locating objects. As understanding of mapping emerges, it may be harder to locate items away from landmarks since it not only requires mapping of landmarks between display and model, but also of distance and direction from landmarks between display and model.

DeLoache and Brown found reliance on landmarks in a task that did not require mapping to a model. They hid a toy in one of a set of identical boxes placed in various locations in a room. Until after two years of age, children only could find the correct box when it was adjacent to a distinctive landmark. In this task, there were several boxes in a complex space, potentially posing a problem of remembering the set of locations. While the study shows early reliance on juxtaposition with distinctive landmarks in coding location, it does not provide a strong test of whether distance coding can be used before two years.

First, to test whether children can code distance from a landmark, the simplest possible task should be used. The task should require locating only a single object, and estimation of distance along a single dimension. Second, in assessing whether young children use distance to code

location, it is important to recognize that estimation of distance by eye will not be exact. Even adults' estimates will be imprecise, and those of young children may be more so. Thus large errors on particular trials do not provide good evidence that a child is not encoding distance even on those trials.

It is possible to determine if, despite inexactness, distance is encoded. The way to do so is to obtain several responses at any true location and then examine the distribution of responses at each of these locations. If the response distributions are centered at or near the corresponding true locations, then those locations must have been coded, albeit inexactly on each particular occasion. A further test of distance coding is to examine if the means of responses are ordered in the same way as are the true locations, with distances between them roughly preserved.

In our study, we examined this question using a trough-shaped sandbox which was five feet long and filled with sand. The sandbox constituted a homogeneous bounded space in which a small object was hidden on each trial. No landmarks were near the box, although there were distal landmarks in the testing room. Children indicated the location of the object by pointing to the spot where it was hidden. Each child saw a toy being hidden once at each of several locations evenly spaced across the box and randomly ordered for each child. The entire session was recorded on videotape and the locations where children pointed at hidden objects were scored from the tapes after the experiment was over. We tested two groups of children. One group was between 6 and 7 years, an age at which distance coding would be expected on this task. The other group was between 16 and 24 months, an age at which many investigators would not expect distance coding to be used.

Let me describe the procedure. For the younger group, child and mother were located on one long side of the box in the middle (about 30 inches from each end). The experimenter was located on the opposite side of the sandbox in the middle while she showed a toy to the child and then hid that toy in the sand. A different small toy was shown on each trial. The mother, who was blindfolded, held the child in a fixed position as the toy was being shown and hidden. After hiding the toy, the experimenter moved away from the box. Before the child was allowed to look for the

toy the mother removed the blindfold and distracted the child. This was done by turning children around and kissing them. Then children were turned back to the original orientation and allowed to look for the toy. The mother then replaced her blindfold and the next trial began. Each child was given nine trials, one at each of nine hiding places such that a toy was shown every six inches.

The procedure for 6 year olds was somewhat different. First, mothers were not present. Second, the child sat in a swivel chair at the middle of the box so that the box was seen from a height similar to that at which the younger children saw it. The experimenter was on the other side of the box while she showed the toy and hid it. After hiding the toy, the experimenter came over to the child's side of the sandbox and turned the child's chair around. She told the child that she was raking the sand to smooth it out. Then she returned the child's chair to its original position. There were 19 positions; the same 9 positions as for the younger children, plus 10 intermediate positions such that a toy was shown at each 3 inches.

Figure 1 shows the data for the 6-year-old children (first graders). The actual positions are shown along the horizontal axis. The means across the children at each position are shown along the vertical axis. If the means were exactly at the true locations, they would fall on the 45 degree line shown here. As you can see, they are close to the line although toys to the left are above and those to the right beneath the line. Figure 2 shows the data displayed in another way. Again the actual locations are shown along the horizontal axis. The vertical axis shows the mean response at each true location minus the true location. If the means of responses were at exactly the true location, the points would fall at zero. Again you can see that true locations were fairly faithfully preserved, but with responses slightly misplaced toward the center of the box.

The critical data can be seen in the next two figures. Figures 3 and 4 show comparable displays for the 16- to 24-month-old group. The first shows departure from 45 degrees. The data are just about identical to those for the six year olds. Here the same data are shown around the zero point. Location is quite accurately preserved. In short, children of 16 months and children over 6 years code the locations of objects in a sandbox similarly, making use of distance in estimating position.

Let me turn now to hierarchical coding of location in young children. I first must tell you a bit about the coding of spatial location by adults. In certain cases, there is systematic bias in adults' spatial reports. In particular, distances between objects may be judged to be greater than they actually are when objects are located in different subsections of a space, and less than they actually are when objects are located in the same subsection of a space. Such distortions reflect hierarchical organization. In a recent paper which I did with Hedges and Duncan, we presented a model of how such biases come about. The model holds that people code location of an object at two levels of detail; a fine grain level consisting of the object's coordinates in a bounded space, and a coarse grain or category level consisting of a subdivision of that bounded space. In estimation, they combine information at the two levels, weighting the remembered fine grain value with a category prototype. The more inexact the fine grain coding, the more weight is given to the prototype. (Huttenlocher, Hedges and Duncan, in press).

In the case we examined, people remembered the location of a dot in a circle. We found that they coded its polar coordinates and its quadrant, represented by a prototype at the center of mass of the quadrant. Let me show you the pattern of bias we found in adults. In Figure 5, the arrows show the direction of displacement of dots; namely, misplacement towards the center of mass of each quadrant. The extent of bias was greater at the center outward than at the circumference inwards, since coding is more exact near the edge.

As a first step in examining the emergence of hierarchical coding and the use of two levels of information in estimation, Elizabeth Hollister gave this circle task to two groups of children. One group was 4 years old and the other group was 10 years old. The pattern of quadrant coding occurs in 10 year olds but not in 4 year olds.

To establish when hierarchical coding first emerges, we wanted to use a simple space, where the subdivision involves only a single dimension. To examine the question we decided to use a space comparable in size to the circle with a paper and pencil task. We presented a rectangle, 20 centimeters long, proportioned like the sandbox. We made up a booklet in which there was a page on which a rectangle with a dot was presented, then a blank page, and then a response page

with an empty rectangle. Subjects placed a dot in the position they had just seen it. We showed dots in 15 locations across the box, one at each location, randomly ordered.

We first tested adults and found that they divided this one dimensional space in half. The observed pattern of bias is shown in Figure 6. We would expect to find displacement from the center and edges of the rectangle if subjects code a fine grain location and a category consisting of the half of the rectangle, and if a category prototype central to each half is used in estimation. The bias outward near the center was greater than the bias inward near the edge, as we expected because distance estimation is less precise at locations far from an edge.

However, the sandbox is a large space and is not necessarily comparable to a small figure. Our initial guess was that hierarchical coding of the location of a dot in a rectangle would emerge sometime after age 6. There were two reasons for the guess. First, for the sandbox, the data at age 6 showed no hierarchical coding. Second, in the circle, evidence of hierarchical coding was lacking at age 4 and was only found at age 10. However, the circle is a more complex form. We tested four groups of subjects, aged 4, 6, 8 and 10 years old; all did this same task.

The next set of figures, 7 and 8, are comparable to those for the sandbox. They show the data for 10 year olds. See a snakelike pattern along the 45 degree line. Evidence of hierarchical organization is most clearly seen by showing true locations subtracted from the mean responses for each true location. The pattern of response shows bias outward from the center in each direction and inward from edges, as would be expected if subjects divide the space in half. Figures 9 and 10 show the data for 6 year olds. The same pattern can be seen along the 45 degree line, and the same pattern of bias outward from the center, showing that the rectangle is divided into two halves.

Finally, let me turn to the 4 year olds. A problem arose in examining whether there was hierarchical organization of the rectangle for the 4 year olds. This was because a sizable number of the children made some mirror image errors. That is, they seemed to be putting their dot approximately the correct distance from the edge, but from the wrong edge. A tendency to place the dot in the mirror image position is a separate issue from that of hierarchical coding. We wanted to see if the data might show hierarchical coding. This issue can be examined by folding the

response distribution at the middle. That is, we plotted true locations at particular distances from the center (or edge) along the horizontal. This placed together two true locations equally distant from the two edges. Along the vertical is the mean of responses collapsed across pairs of locations equally distant from the edges. First I will show you the data analyzed this way for first graders, who you know organize the space hierarchically. They are shown in figures 11 and 12. The comparable data for 4 year olds are shown in figures 13 and 14. As you can see, the data for 4 year olds and for 6 year olds are parallel. However, there is greater bias for the 4 year olds, as we expected because there is greater inexactness. In short, the 4 year olds organize the rectangle at two levels of detail as do adults.

The reason why the rectangle in the paper and pencil task is hierarchically organized by age 4 but the sandbox is not so organized even by age 6 is not yet clear. Clearly, we must find out what adults do with the sandbox. It seems most likely that the shape of the sandbox as an overall figure may be difficult to encode by young children because it is so large an object.

In any case, the following conclusions can be drawn from our work thus far. Children by 16 months use distance in coding location. This is the earliest age our sandbox procedure can be used. Possibly with a suitable procedure they can be shown to do so much earlier. By 4 years, the youngest age our procedure of marking location in a paper and pencil task could be used, there is evidence that, for a small simple bounded form, children represent location at two levels and combine information across levels in estimating location. Thus adult forms of spatial coding emerge very early in childhood.

FIGURE 1

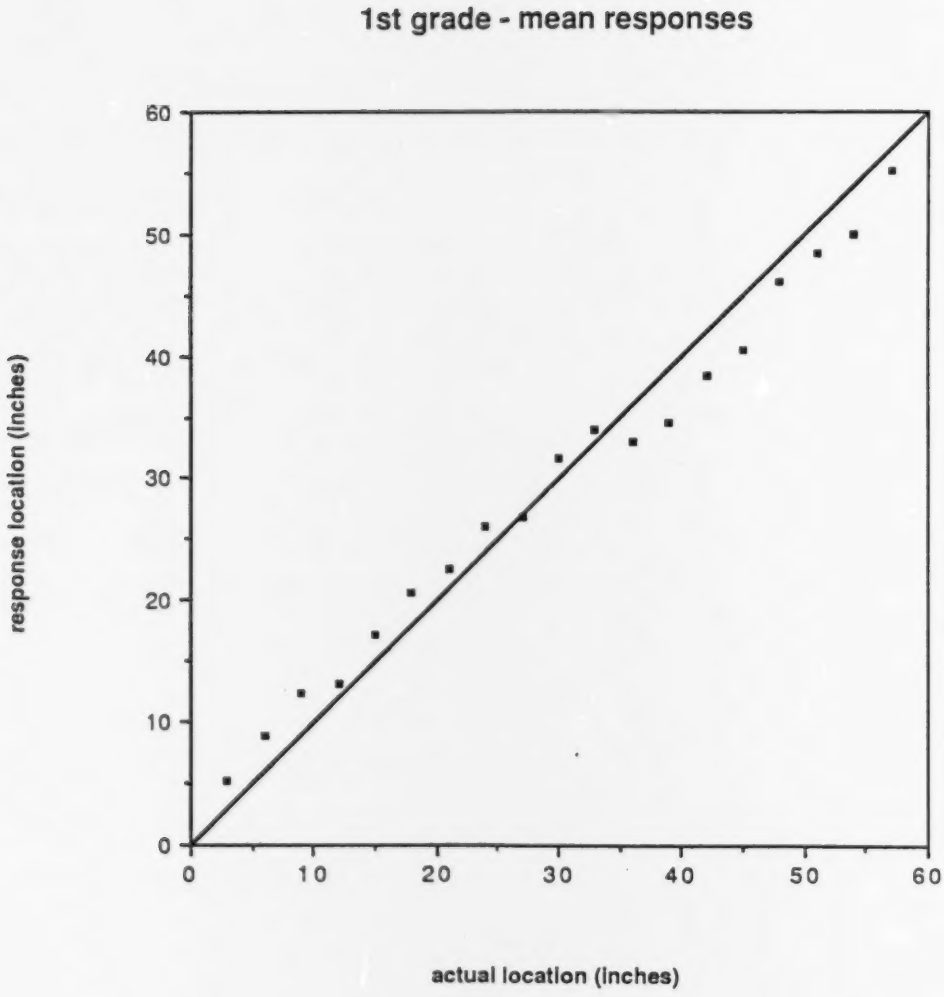
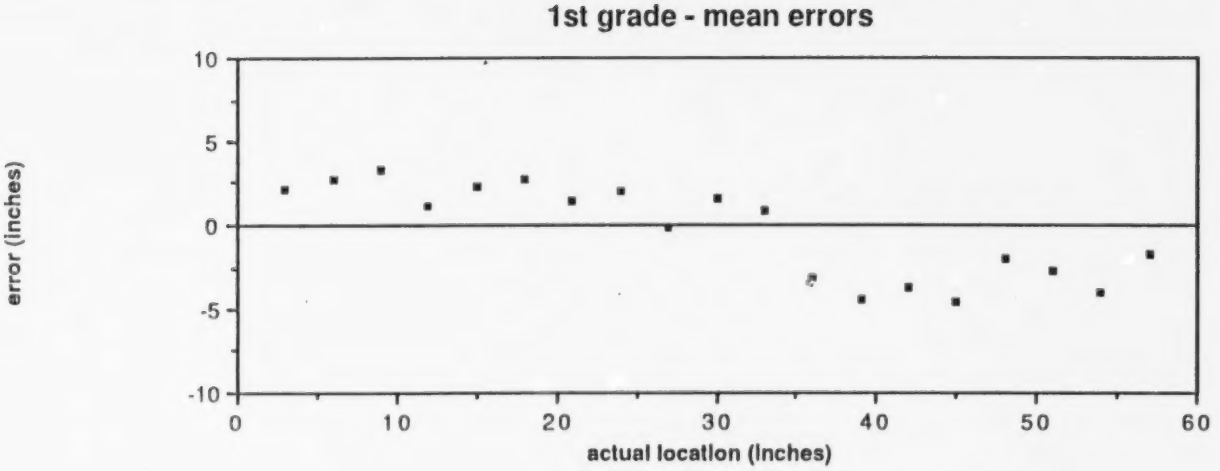

1st grade - mean responses
response location (inches)
actual location (inches)
0
10
20
30
40
50
60

FIGURE 2


1st grade - mean errors
error (inches)
10
5
0
-5
-10
0
10
20
30
40
50
60
actual location (inches)

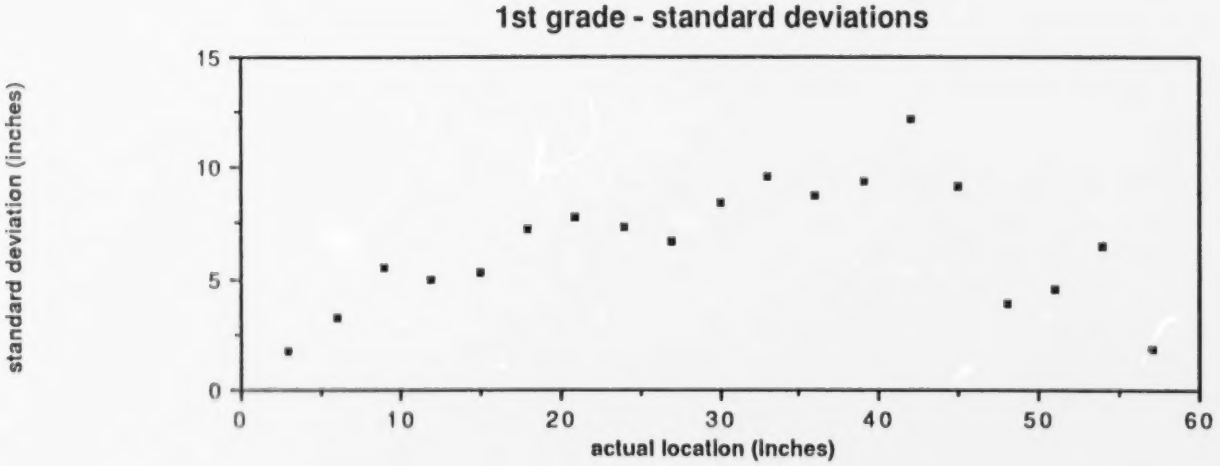

1st grade - standard deviations
standard deviation (inches)
15
10
5
0
0
10
20
30
40
50
60
actual location (inches)

FIGURE 3

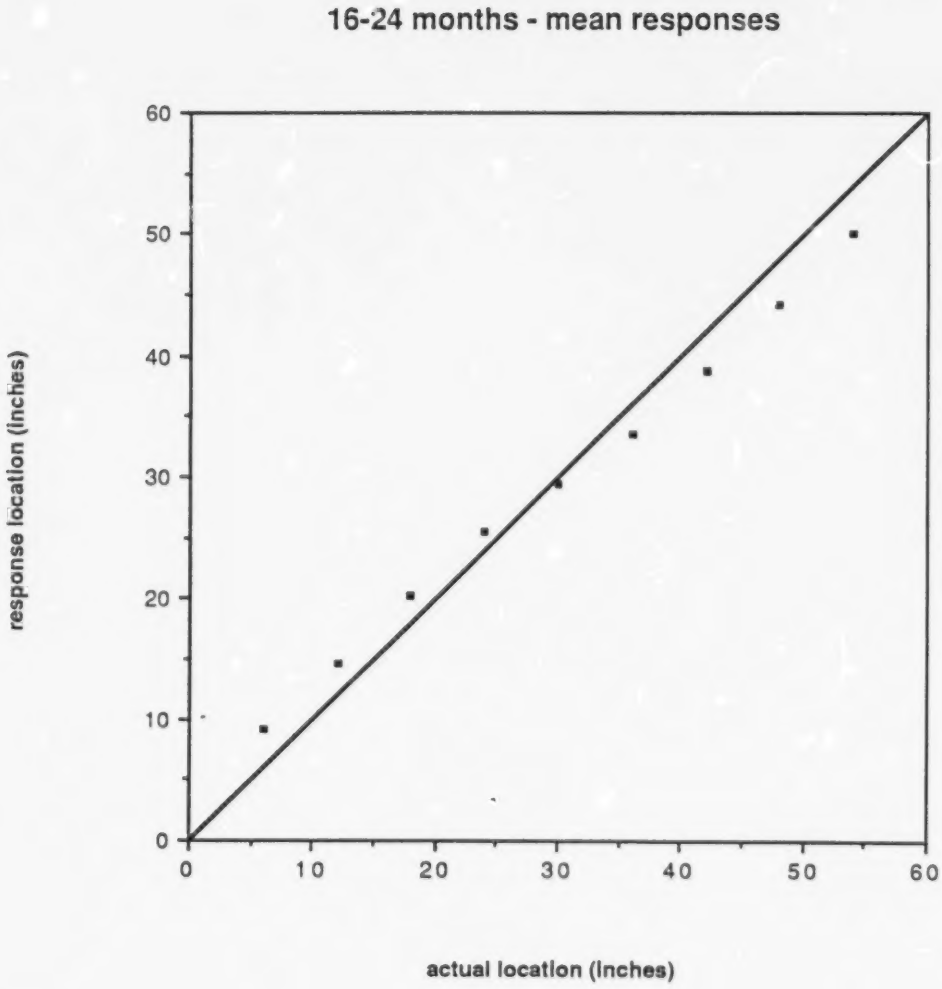
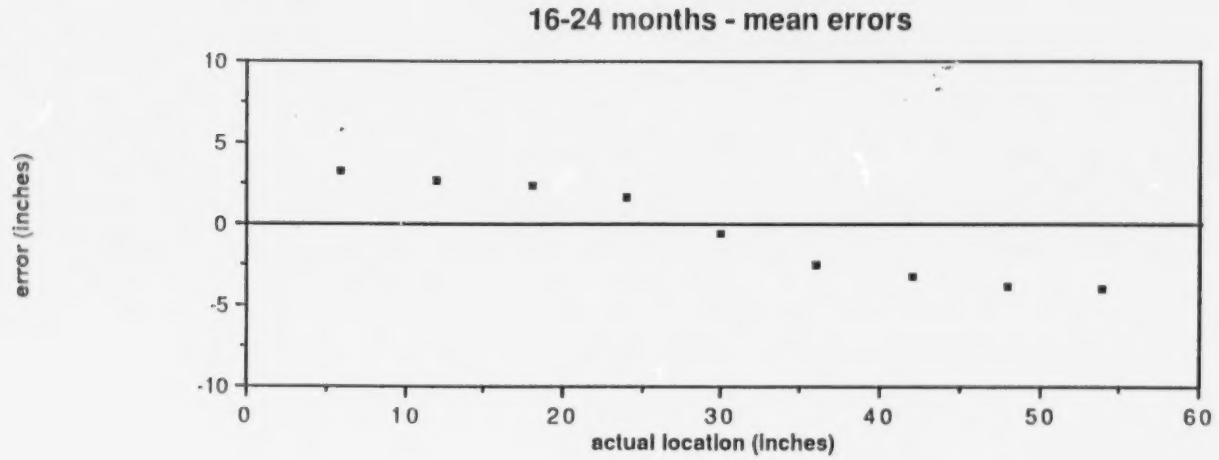

16-24 months - mean responses
response location (inches)
actual location (inches)
0
10
20
30
40
50
60

FIGURE 4


16-24 months - mean errors
error (inches)
10
5
0
-5
-10
0
10
20
30
40
50
60
actual location (inches)

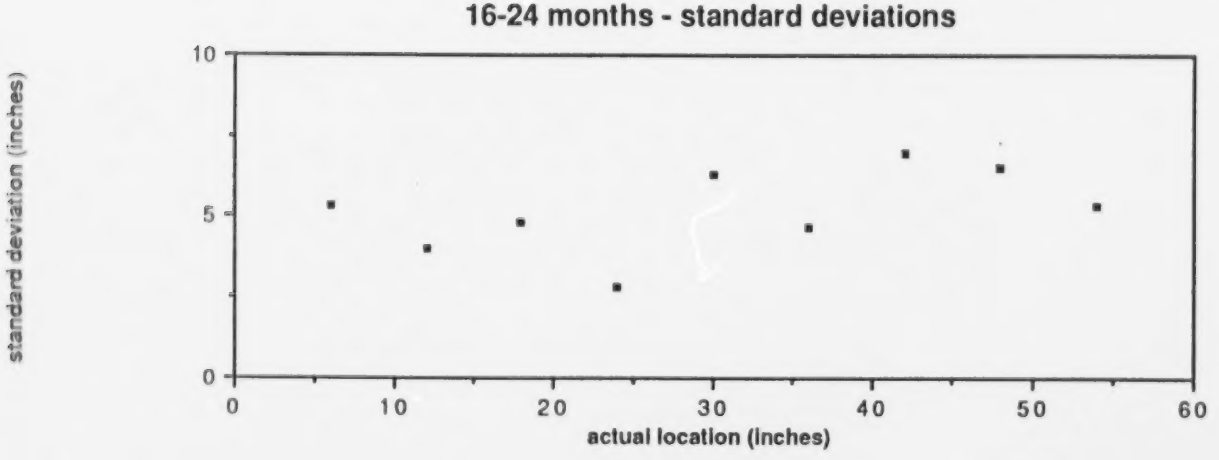

16-24 months - standard deviations
standard deviation (inches)
10
5
0
0
10
20
30
40
50
60
actual location (inches)

FIGURE 5

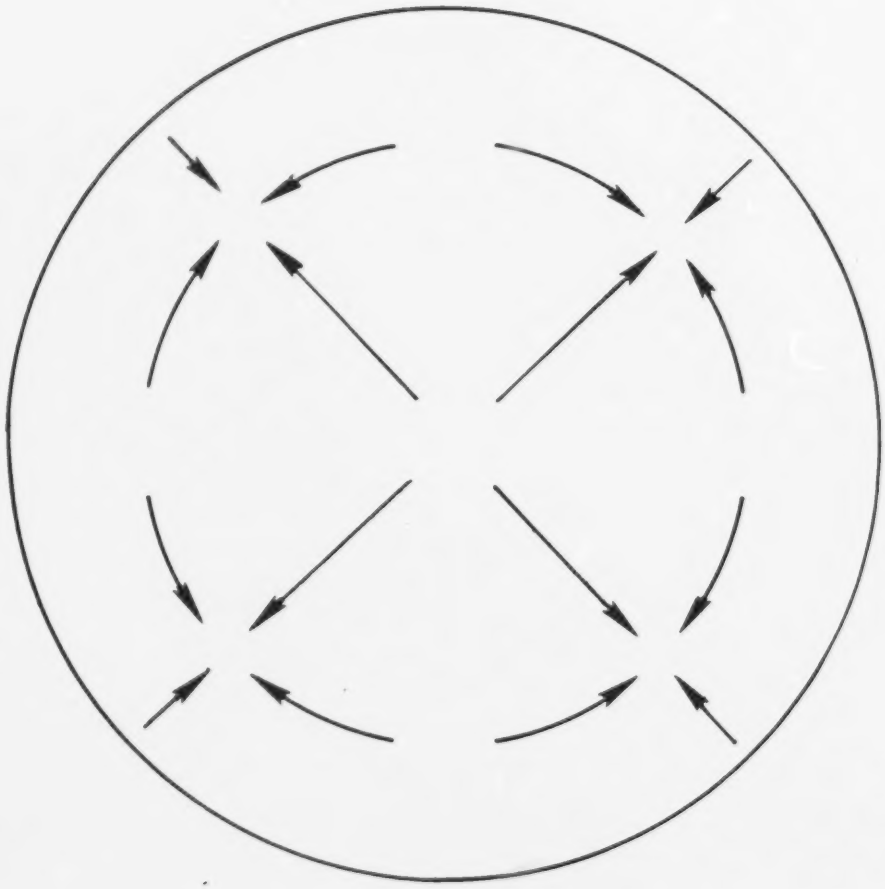


FIGURE 6

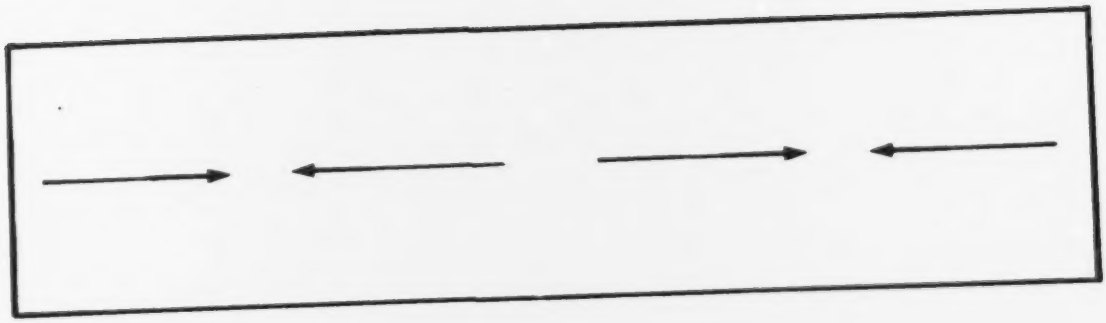


FIGURE 7

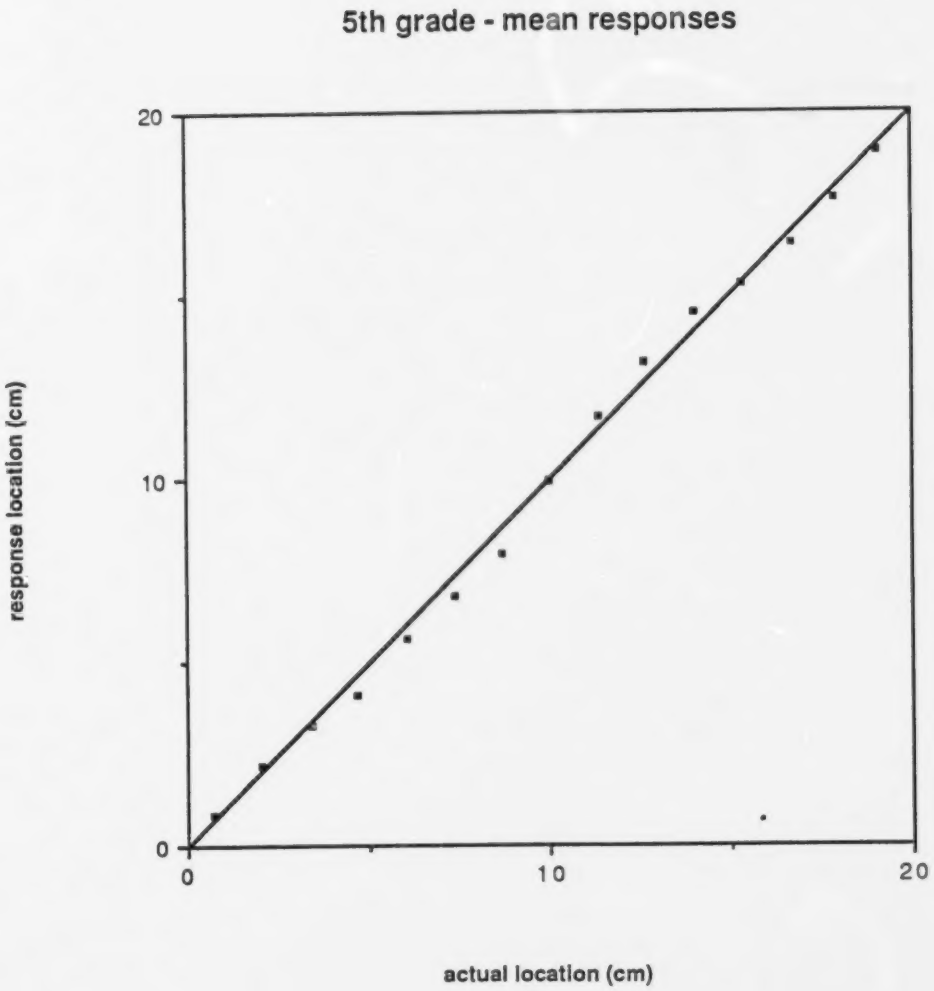

5th grade - mean responses
response location (cm)
20
10
0
0
10
20
actual location (cm)

FIGURE 8

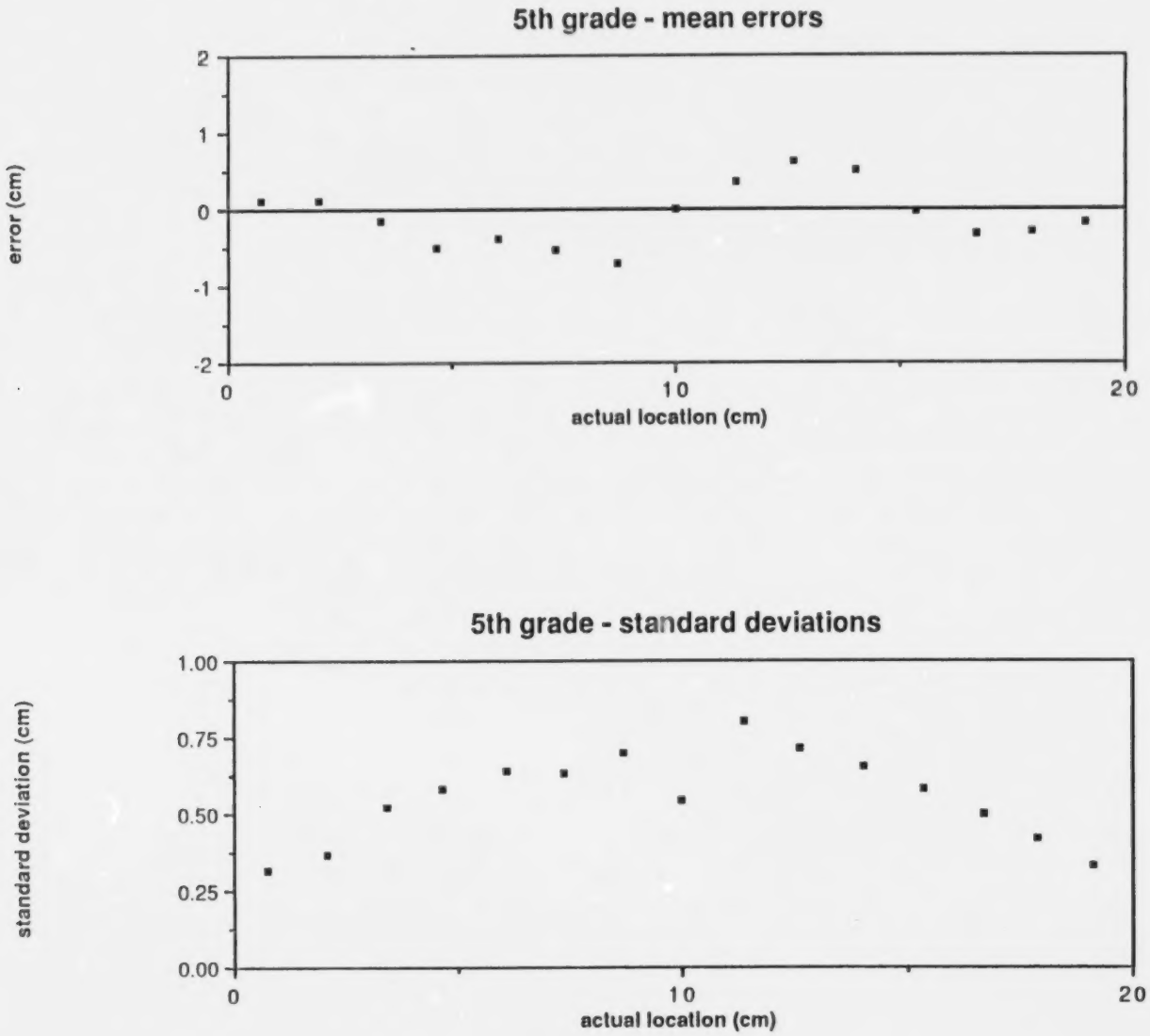

5th grade - mean errors
error (cm)
2
1
0
-1
-2
0
10
20
actual location (cm)
5th grade - standard deviations
standard deviation (cm)
1.00
0.75
0.50
0.25
0.00
0
10
20
actual location (cm)

FIGURE 9

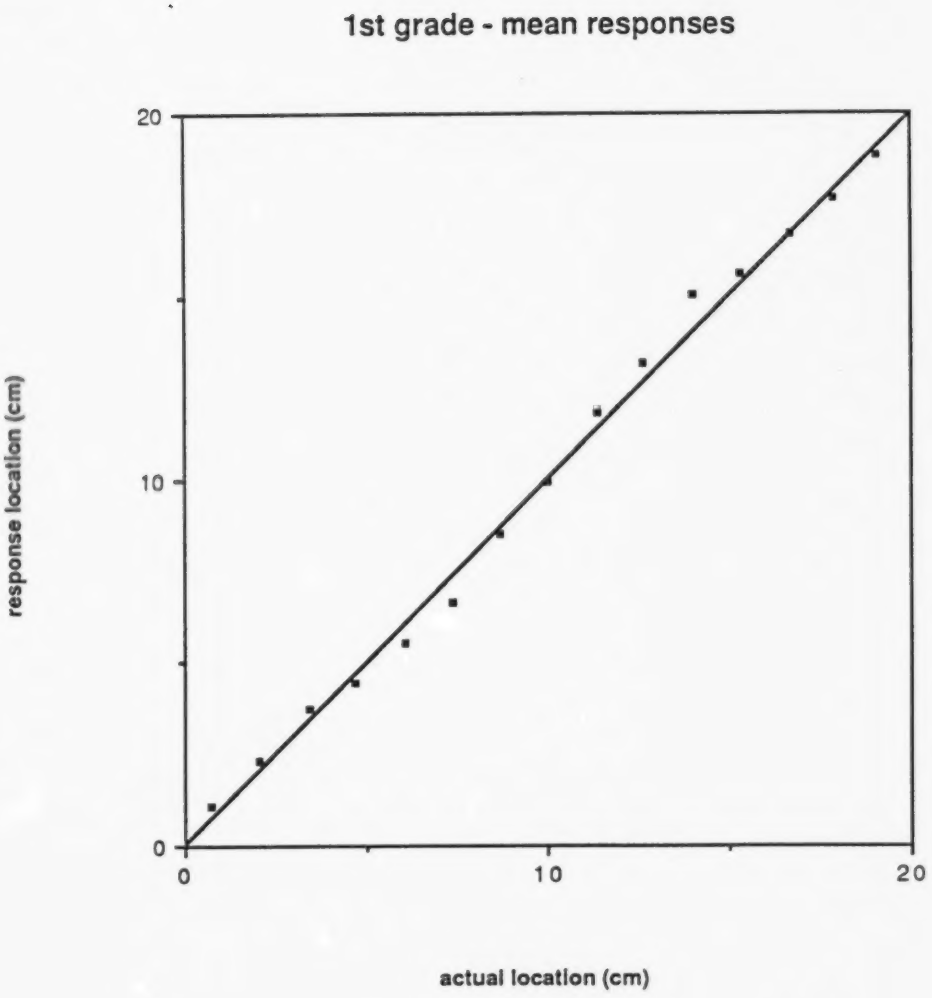
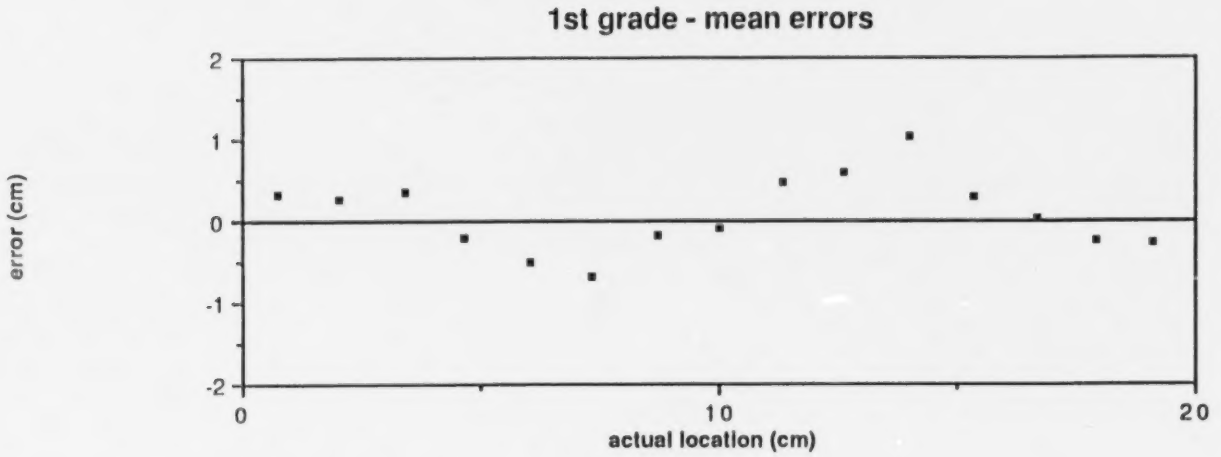

1st grade - mean responses
response location (cm)
20
10
0
0
10
20
actual location (cm)

FIGURE 10


1st grade - mean errors
error (cm)
2
1
0
-1
-2
0
10
20
actual location (cm)

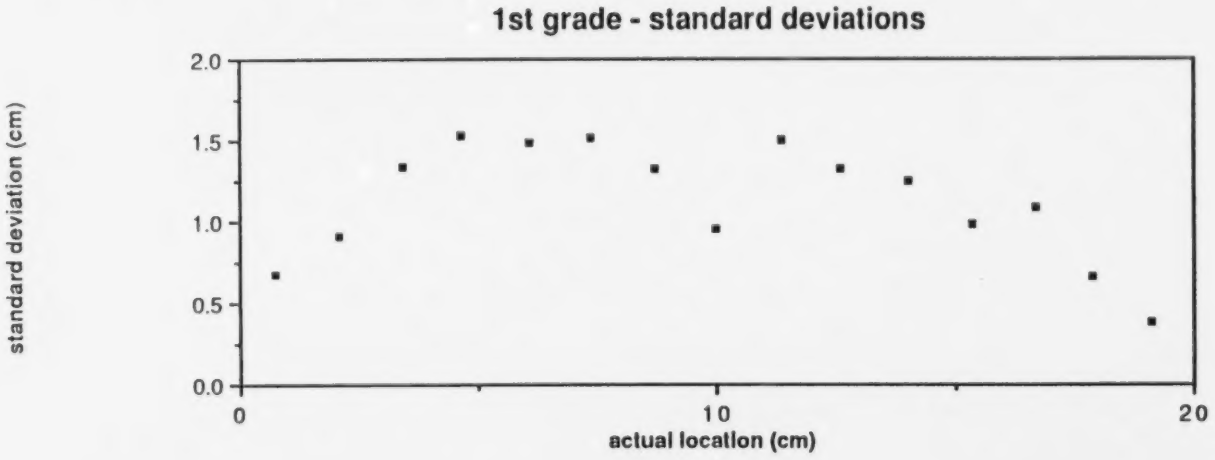
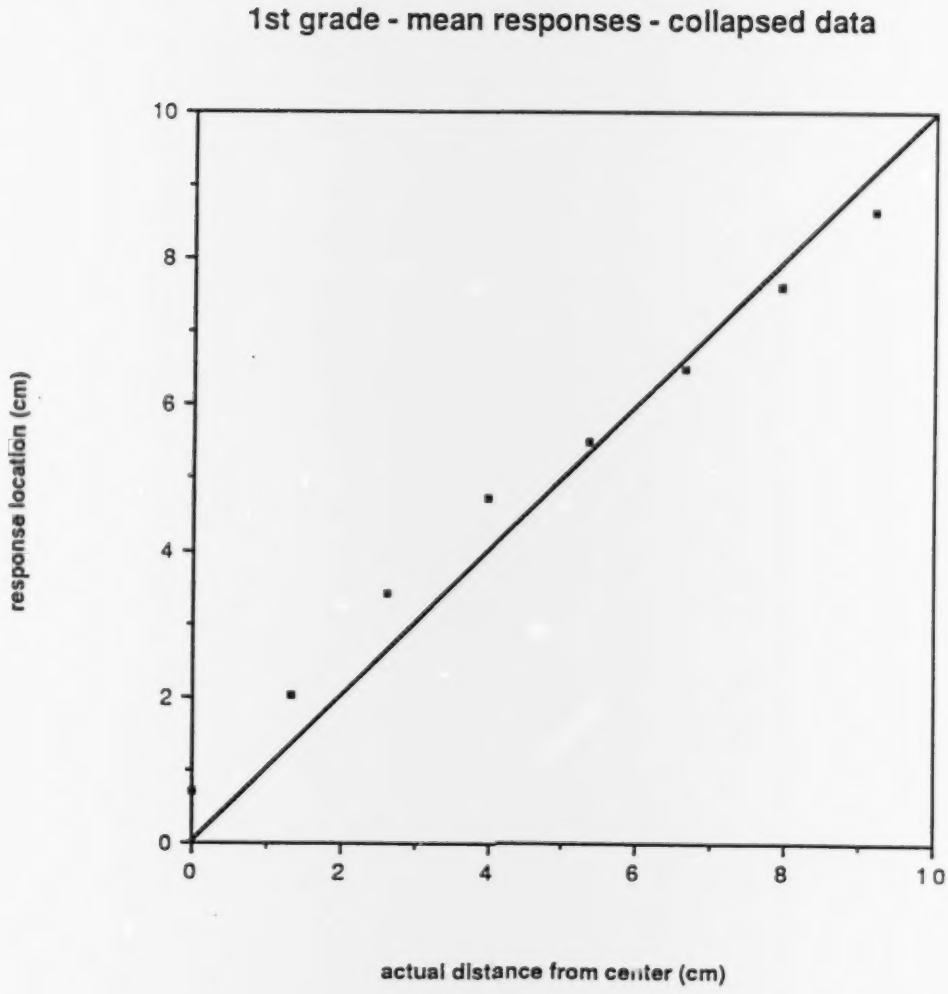
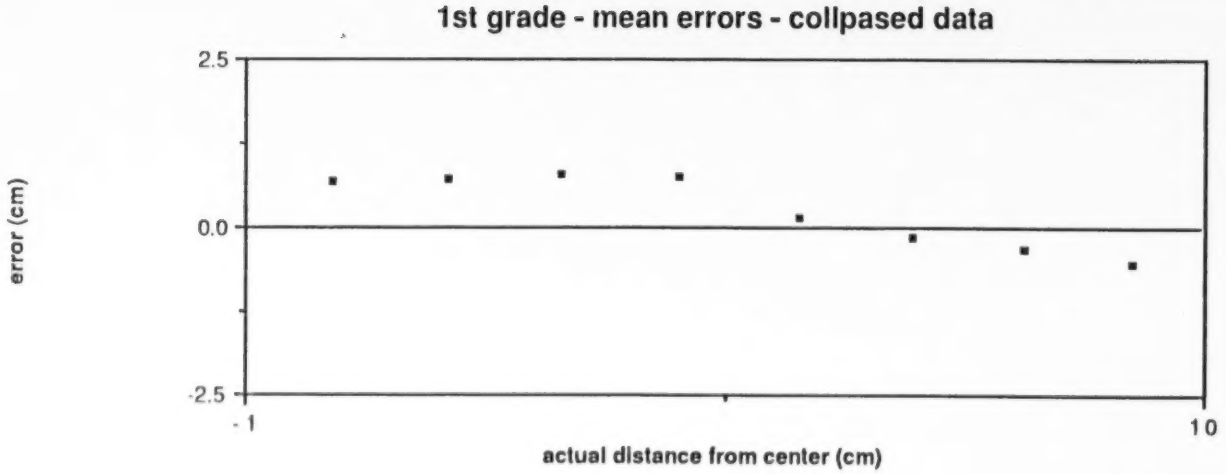

1st grade - standard deviations
standard deviation (cm)
2.0
1.5
1.0
0.5
0.0
0
10
20
actual location (cm)

FIGURE 11


1st grade - mean responses - collapsed data
response location (cm)
actual distance from center (cm)
0
2
4
6
8
10


1st grade - mean errors - collpased data
2.5
0.0
-2.5
error (cm)
- 1
10
actual distance from center (cm)

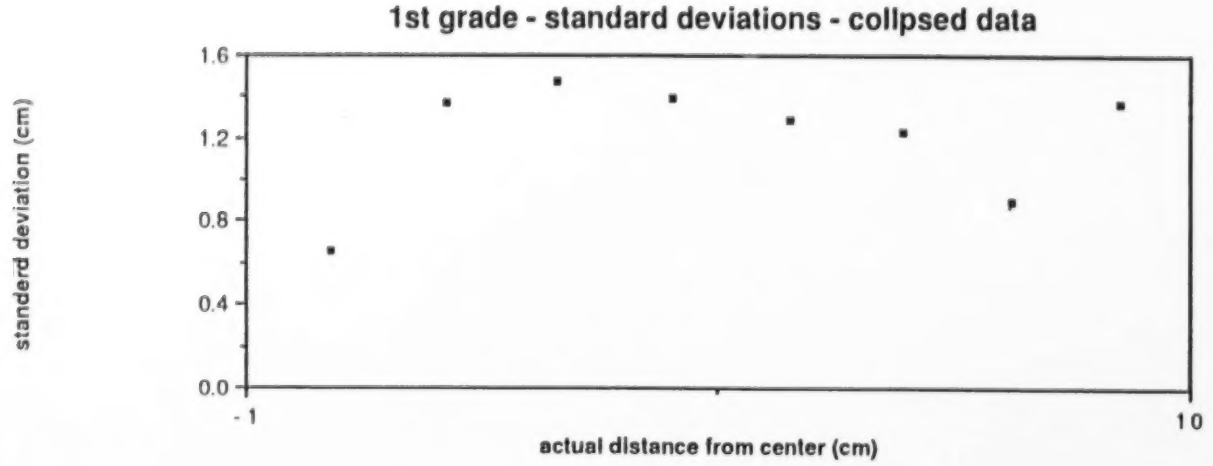

1st grade - standard deviations - collpsed data
1.6
1.2
0.8
0.4
0.0
standerd deviation (cm)
- 1
10
actual distance from center (cm)

FIGURE 13

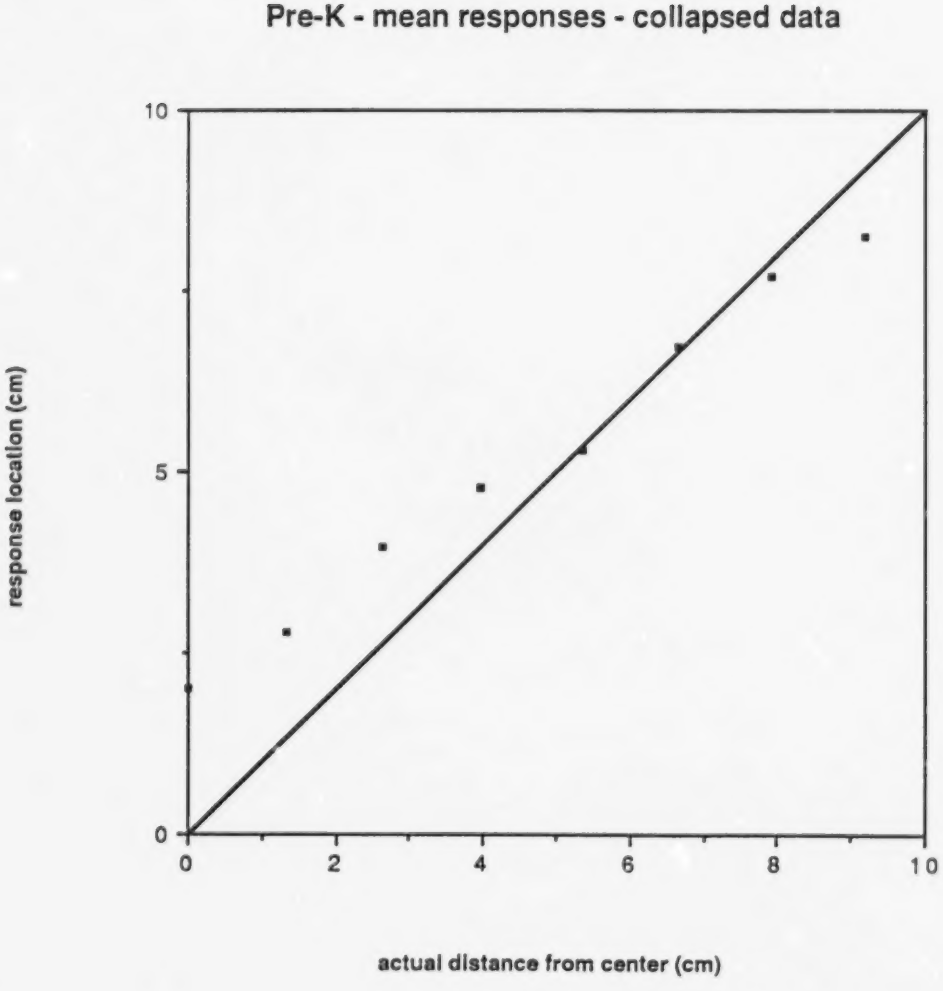
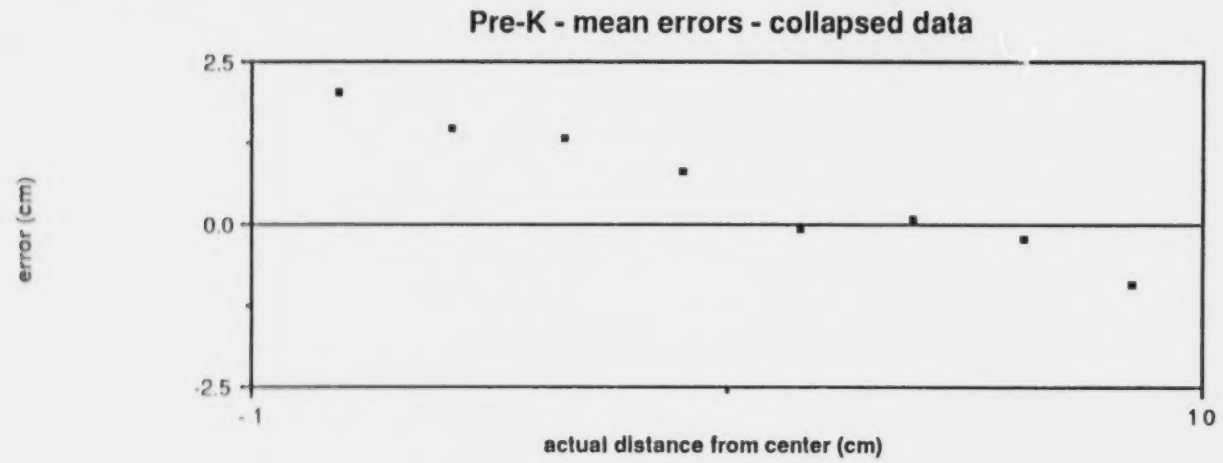
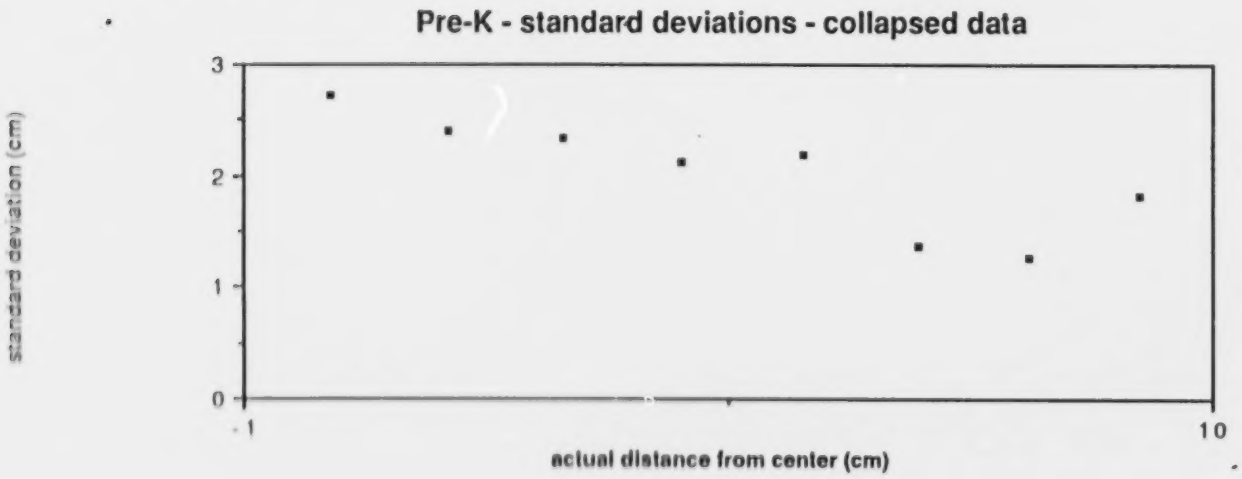

Pre-K - mean responses - collapsed data
response location (cm)
10
5
0
0
2
4
6
8
10
actual distance from center (cm)

FIGURE 14


Pre-K - mean errors - collapsed data
2.5
0.0
-2.5
error (cm)
-1
10
actual distance from center (cm)


Pre-K - standard deviations - collapsed data
3
2
1
0
standard deviation (cm)
-1
10
actual distance from center (cm)